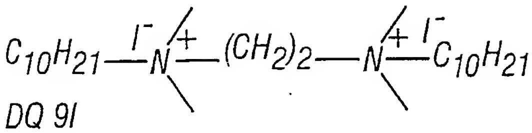
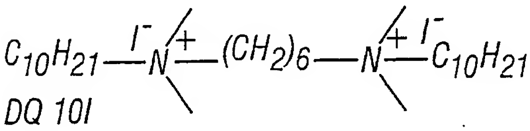
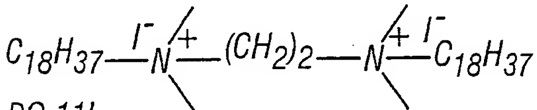


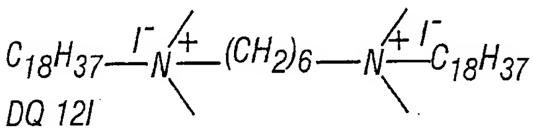
DQ 9I



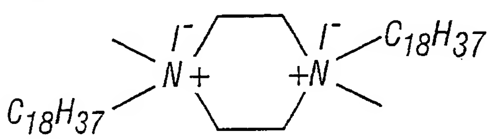
DQ 10I



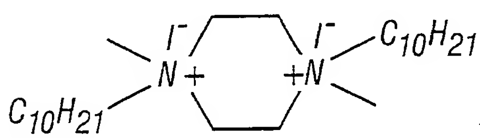
DQ 11I



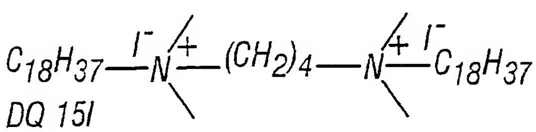
DQ 12I



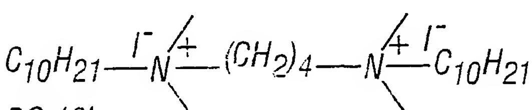
DQ 13I



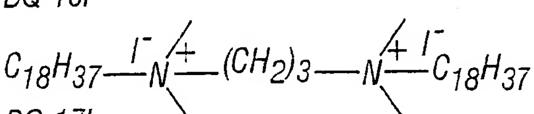
DQ 14I



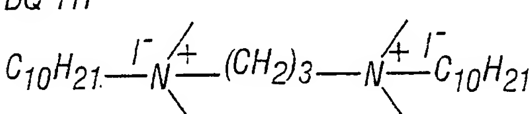
DQ 15I



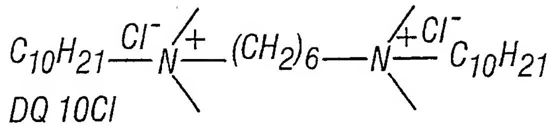
DQ 16I



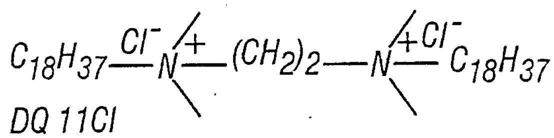
DQ 17I



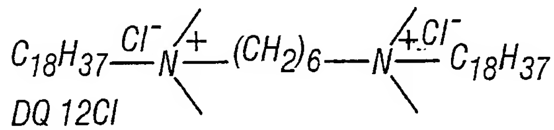
DQ 18I



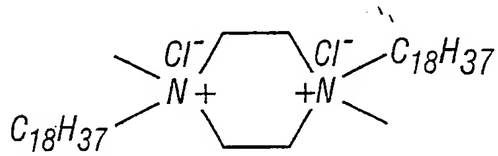
DQ 10Cl



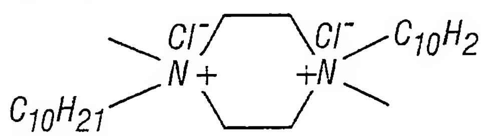
DQ 11Cl



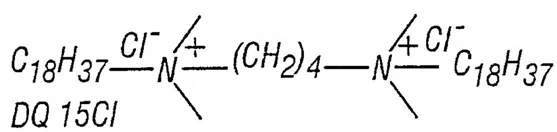
DQ 12Cl



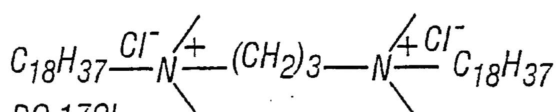
DQ 13Cl



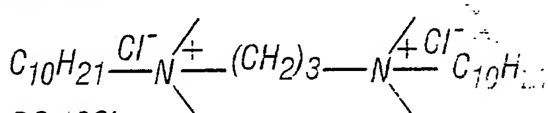
DQ 14Cl



DQ 15Cl



DQ 17Cl



DQ 18Cl

FIG. 1

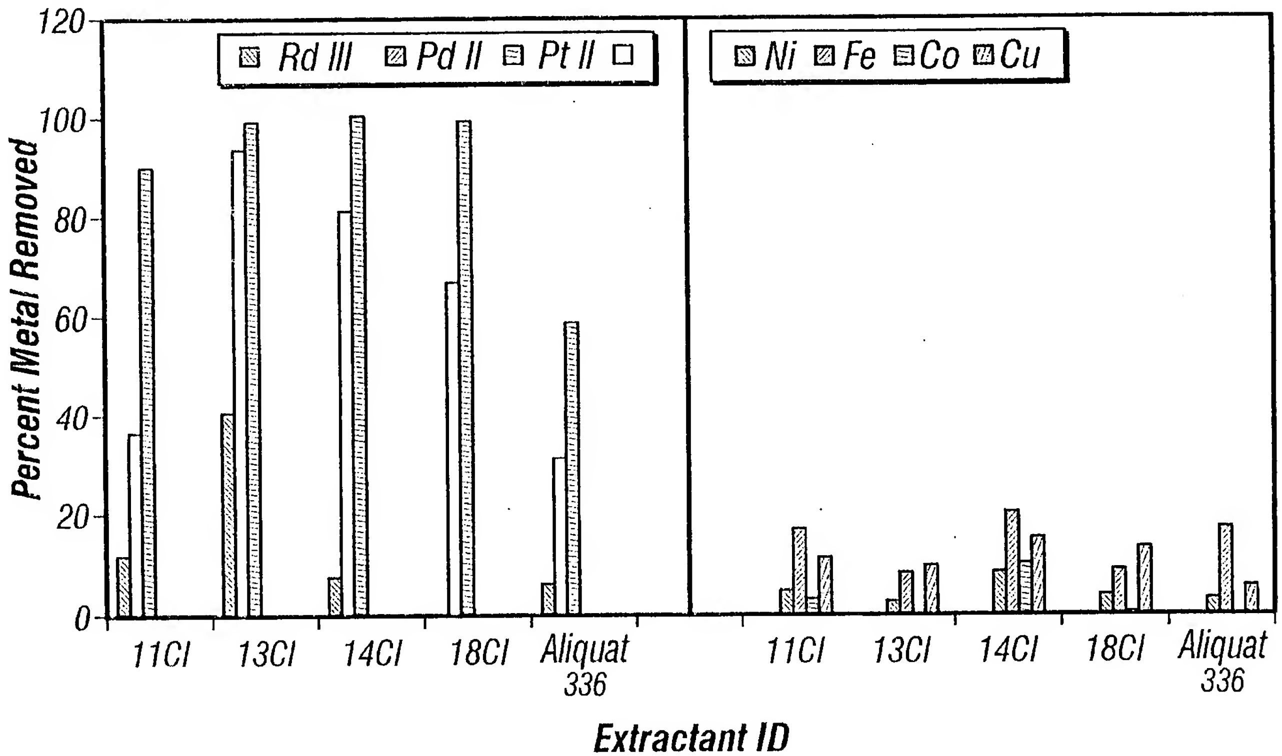

Rd III
Pd II
Pt II
Ni
Fe
Co
Cu
120
100
80
60
40
20
0
Percent Metal Removed
11Cl
13Cl
14Cl
18Cl
Aliquat 336
11Cl
13Cl
14Cl
18Cl
Aliquat 336
Extractant ID

FIG. 2

Compound	*D-Value Pd II*	*Conformation Minimum Energy (kcal/mole)*	*Connectivity Index (order 2, standard) D*	*Dipole Moment (debye) E*	*Electron Affinity (eV) F*
DQ 18	*2.86*	*39.331*	*11.632*	*12.744*	*7.127*
DQ 16		*39.449*	*11.985*	*2.933*	*6.601*
DQ 10	*1.75*	*40.322*	*12.692*	*0.01*	*5.948*
DQ 14	*2.6*	*39.924*	*11.071*	*25.323*	*8.122*
DQ 17	*3.3*	*50.797*	*17.289*	*25.52*	*7.139*
DQ 15	*0.42*	*49.902*	*17.642*	*0.025*	*6.597*
DQ 12	*1.59*	*50.899*	*18.349*	*0.124*	*5.946*
DQ 13	*3.22*	*50.293*	*16.728*	*52.726*	*8.119*
DQ11	*0.89*	*49.694*	*16.935*	*0.148*	*7.867*

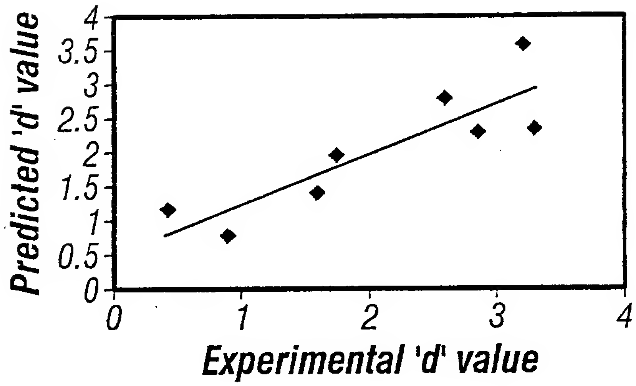
FIG. 3A

Compound	Dielectric Energy (kcal)/mole) G	Steric Energy (kcal/mole) H	Total Energy (Hartree) I	Heat of Formation (kcal/mole)	HOMO Energy (ev)
DQ 18	7.7	39.331	214.593	258.295	13.703
DQ 16	7.211	39.597	221.775	242.427	13.635
DQ 10	6.602	40.322	236.121	218.102	13.52
DQ 14	8.438	39.924	205.938	291.32	13.855
DQ 17	7.759	50.797	329.153	171.131	12.628
DQ 15	7.301	49.902	336.331	155.69	12.601
DQ 12	6.62	50.899	350.679	131.143	12.552
DQ 13	8.487	50.293	320.496	204.337	12.687
DQ11	8.312	49.694	321.968	190.296	12.661

FIG. 3B

Compound	Ionization Potential (eV) L	Log P M	LUMO (eV) Energy N	Shape Index (basic kappa, order 3) O	Valence Connectivity Index (order 2, standard) Q	Solvent Accessible Surface Area (Å^2) P
DQ 18	13.703	6.409	-7.127	21.031	521.24	11.069
DQ 16	13.635	6.86	-6.601	22.027	539.815	11.423
DQ 10	13.52	7.653	-5.948	23.967	576.054	12.13
DQ 14	13.855	6.179	-8.122	13.04	485.397	10.53
DQ 17	12.628	12.75	-7.139	36.681	813.7	16.726
DQ 15	12.601	13.201	-6.598	37.686	831.853	17.08
DQ 12	12.552	13.993	5.946	39.658	883.721	17.787
DQ 13	12.687	12.52	-8.119	26.747	778.615	16.187
DQ11	12.661	12.697	-7.867	35.716	793.278	16.372

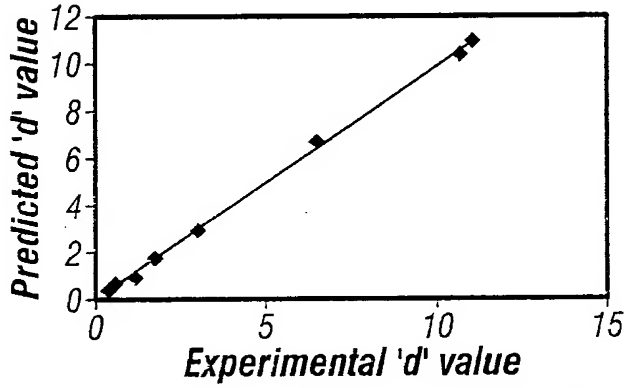
FIG. 3C



Predictive Eq. for Pd II

B=0.0554277*E+0.610452*L-16.7616/N-9.0729

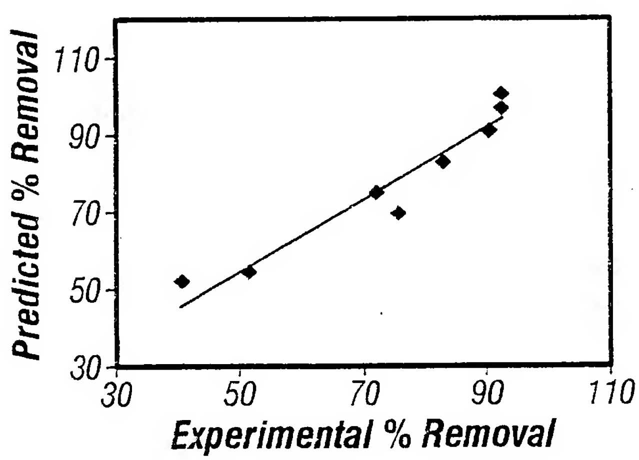
FIG. 4A



Predictive Eq. for Pd IV

B=71.6336*D+0.463796*E+23.6272*F+19.8848*G-9.37422*H+2.71931*I+108.256

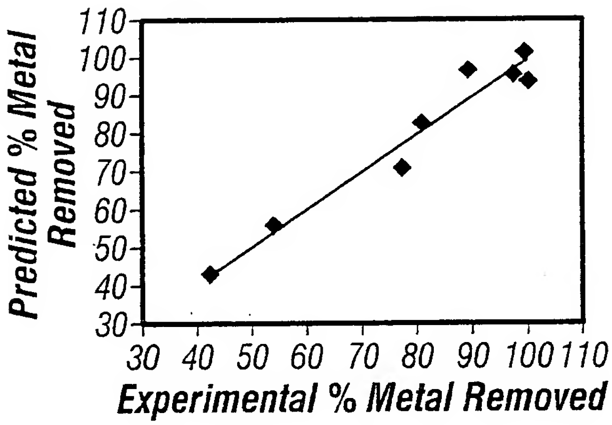
FIG. 4B



Predictive Eq. for Pt II

B=-276.194*L-69.6714*M-4.68162*N-7.67628*O+3.7778*P-154.864*Q+4211.14

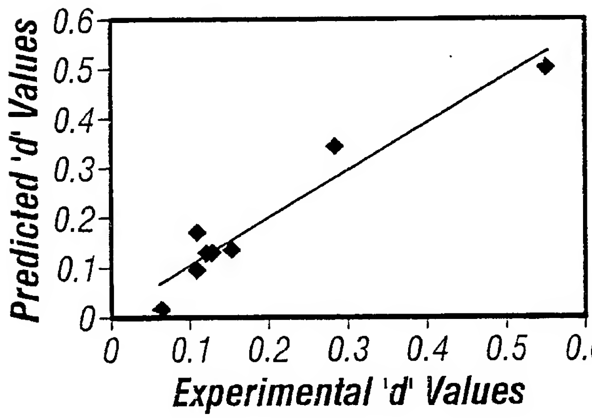
FIG. 4C



Predictive Eq. for Pt IV

B=283.378*D+1.4239
9*E+173.825*F+212.2
66*G+2.69479*H+14
4354*I+167.3

FIG. 4D



Predictive Eq. for Rh III

B=0.00584793*E-
0.90334*N-42.1486/N-
12.3346

FIG. 4E

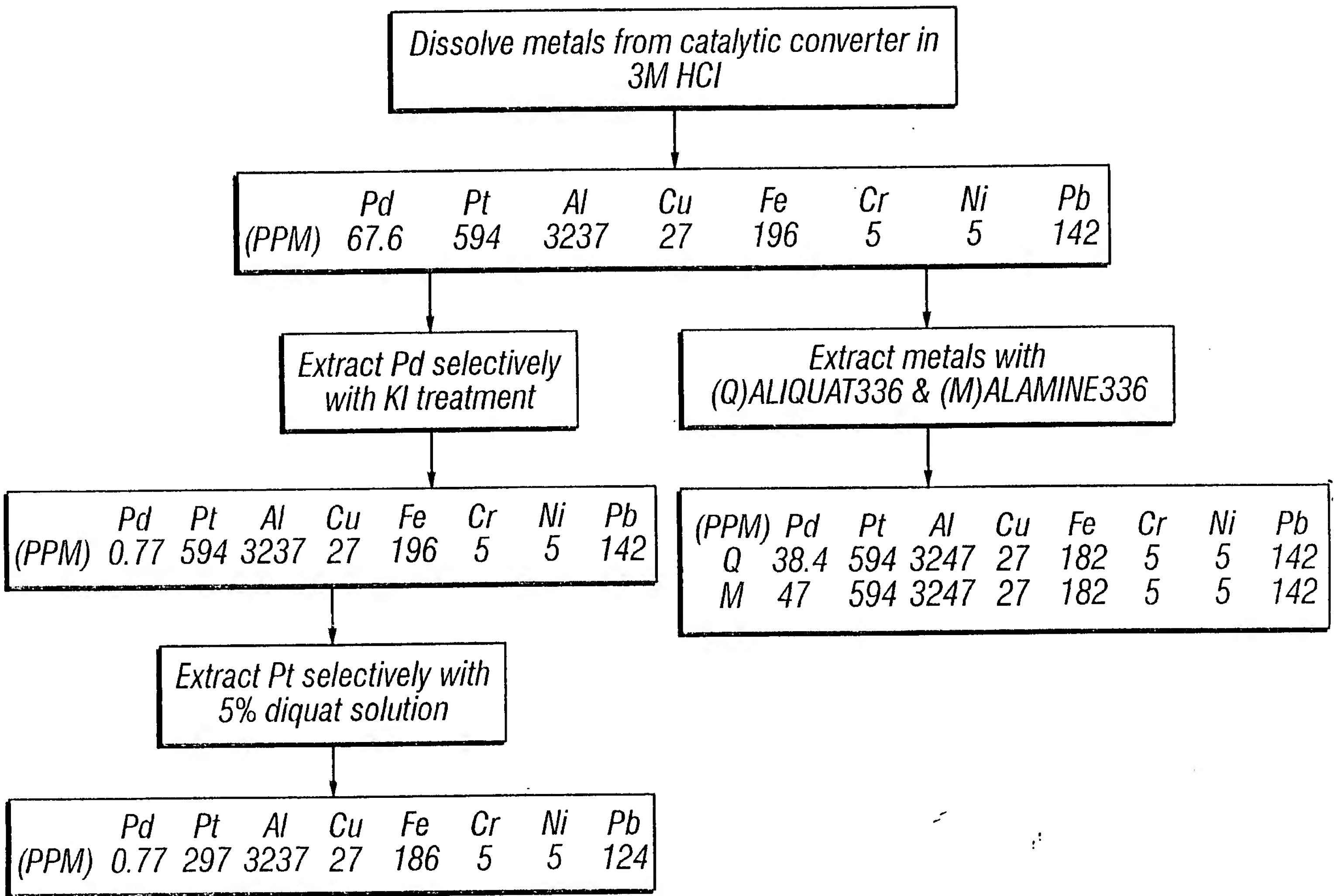

Dissolve metals from catalytic converter in 3M HCl
Pd Pt Al Cu Fe Cr Ni Pb
(PPM) 67.6 594 3237 27 196 5 5 142
Extract Pd selectively with KI treatment
Pd Pt Al Cu Fe Cr Ni Pb
(PPM) 0.77 594 3237 27 196 5 5 142
Extract Pt selectively with 5% diquat solution
Pd Pt Al Cu Fe Cr Ni Pb
(PPM) 0.77 297 3237 27 186 5 5 124
Extract metals with (Q)ALIQUAT336 & (M)ALAMINE336
(PPM) Pd Pt Al Cu Fe Cr Ni Pb
Q 38.4 594 3247 27 182 5 5 142
M 47 594 3247 27 182 5 5 142

FIG. 5

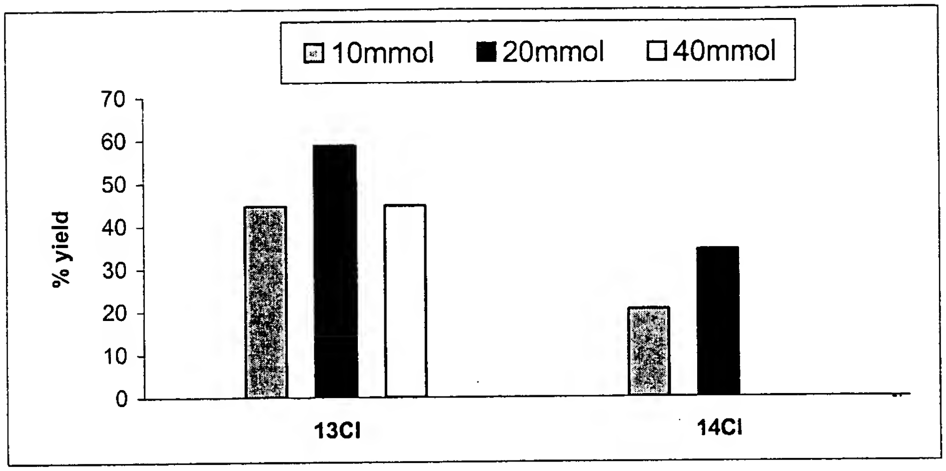


Figure 6. Effect of scale up of synthesis on yields of the reaction

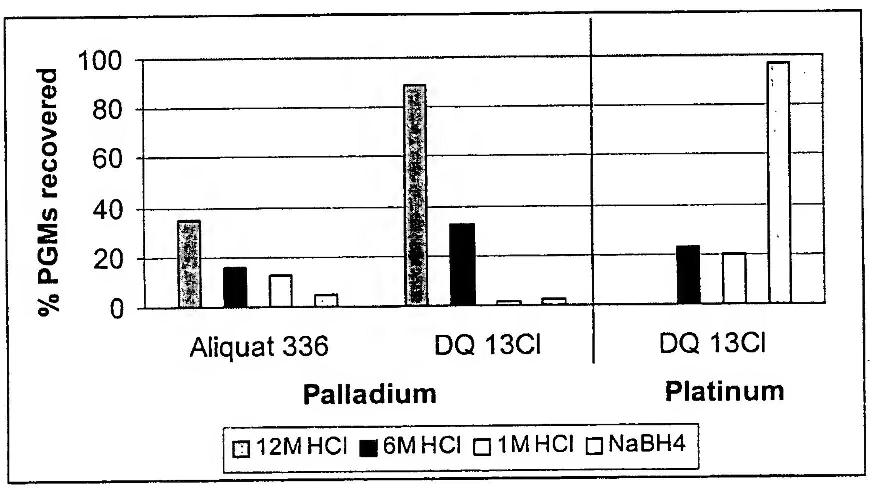


Figure 7. Comparison of % of PGMs recovered during back extraction experiments

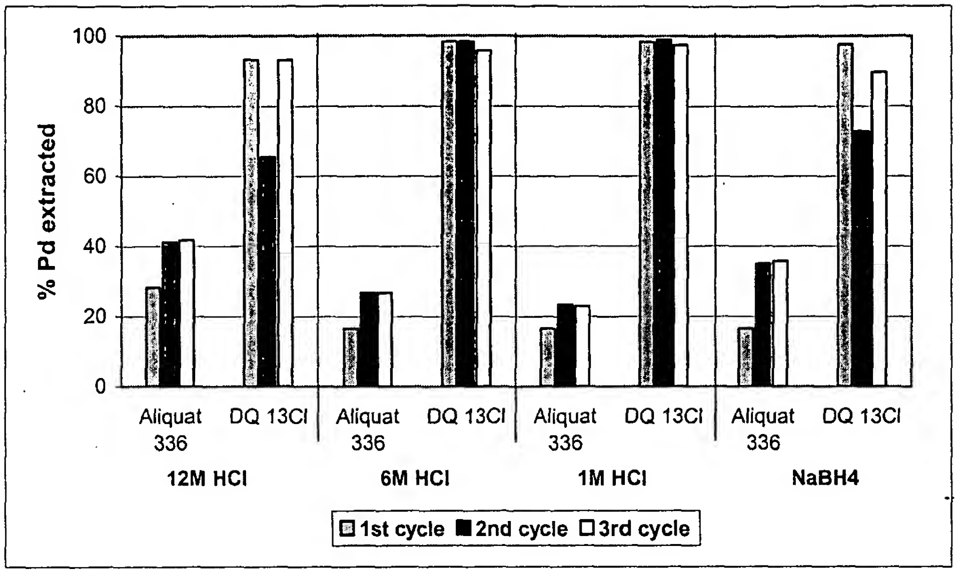


Figure 8. Comparison of efficiency of diquats in multiple extractions

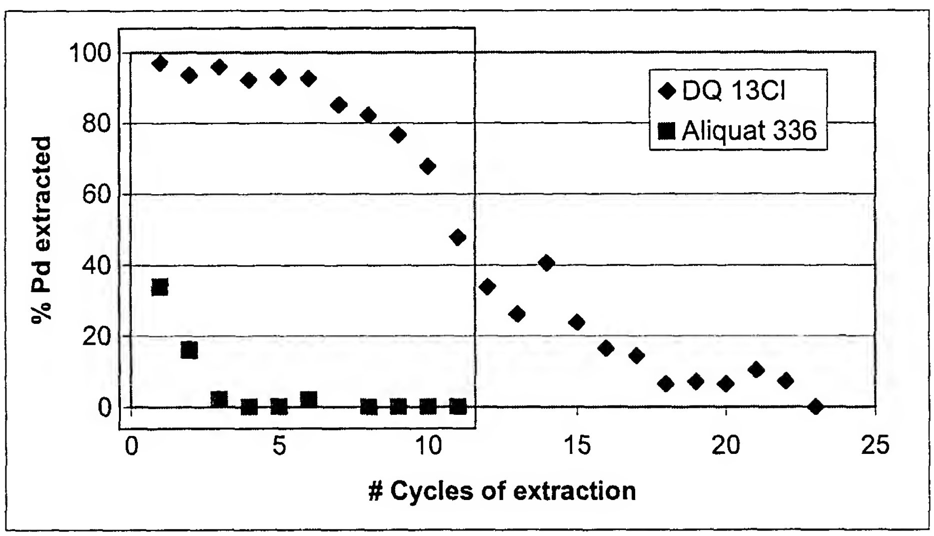


Figure 9. Efficiency of DQ 13Cl in continuous Pd extractions

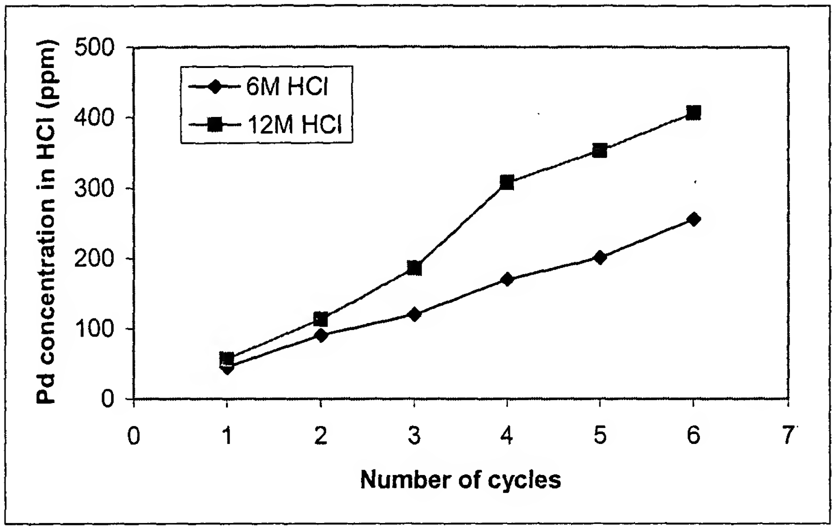


Figure 10. Concentration of Pd back-extracted in HCl

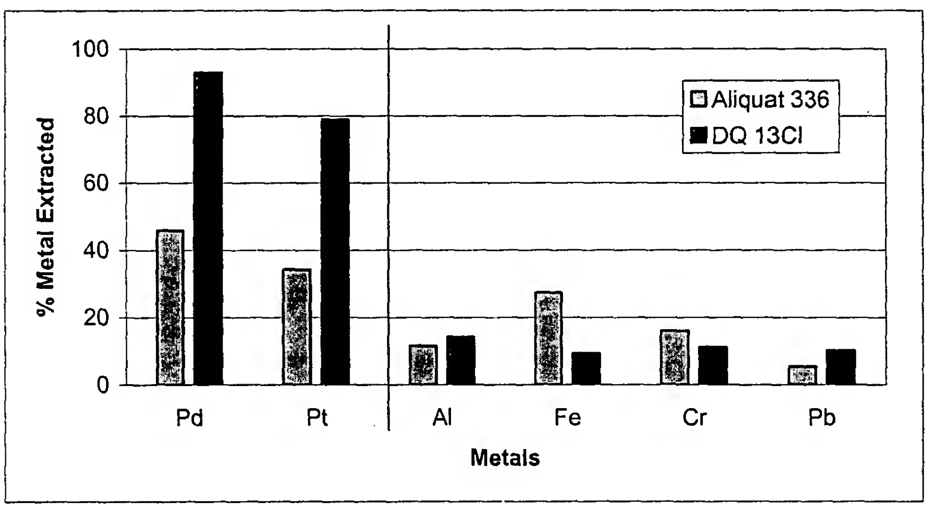


Figure 11. Selectivity of diquats towards extractability of PGMs from base metals

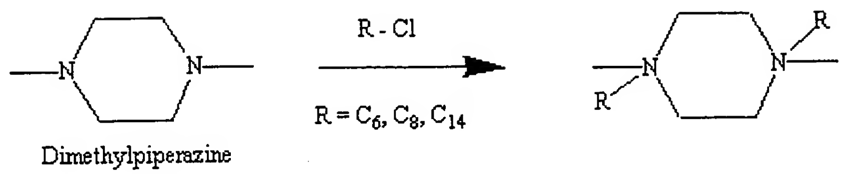


Figure 12. Synthetic scheme for synthesis of new diquaternary amine compounds

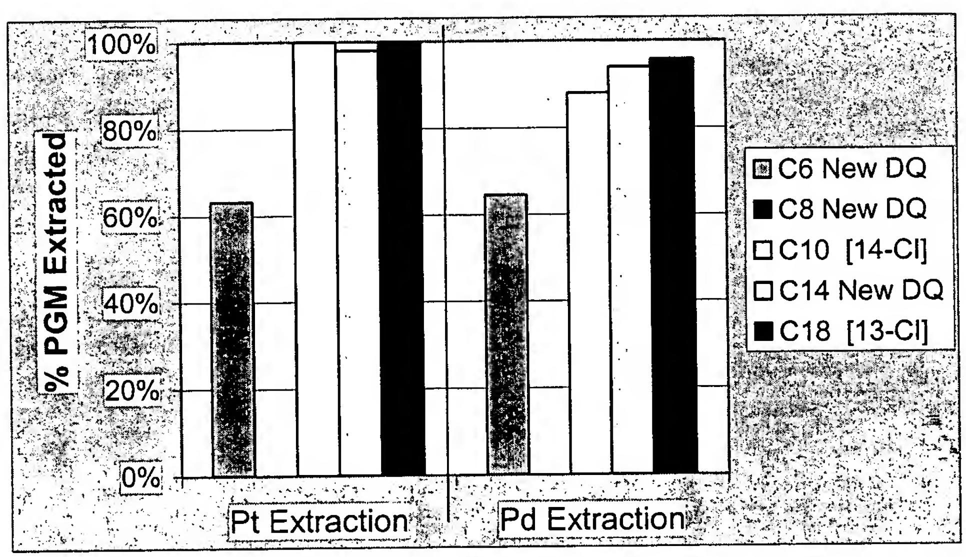


Figure 13. Longer side chain substitution increases PGM extraction efficiency

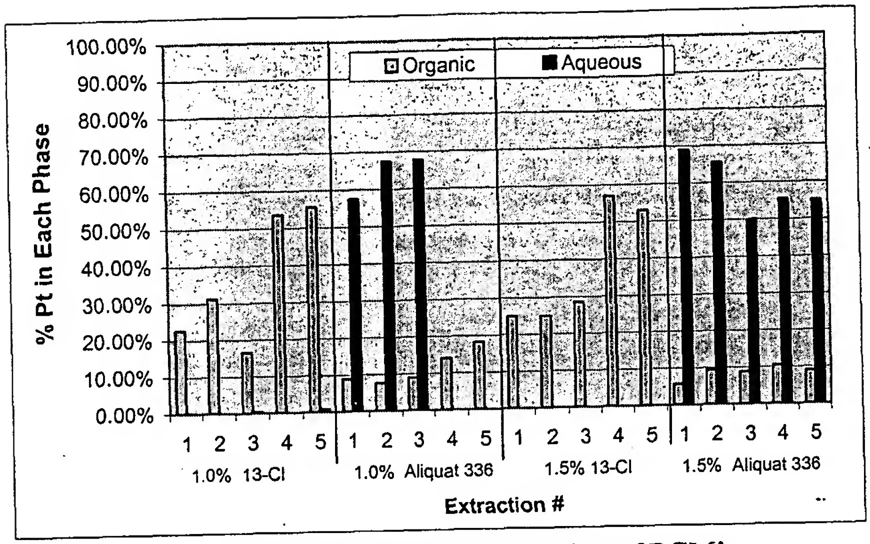


Figure 14. Material Balance Investigation of PGM's

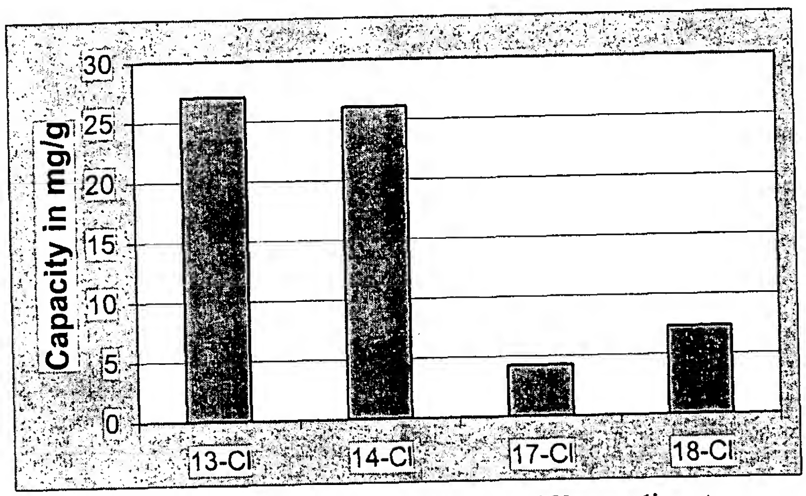


Figure 15. Binding Capacities of different diquats

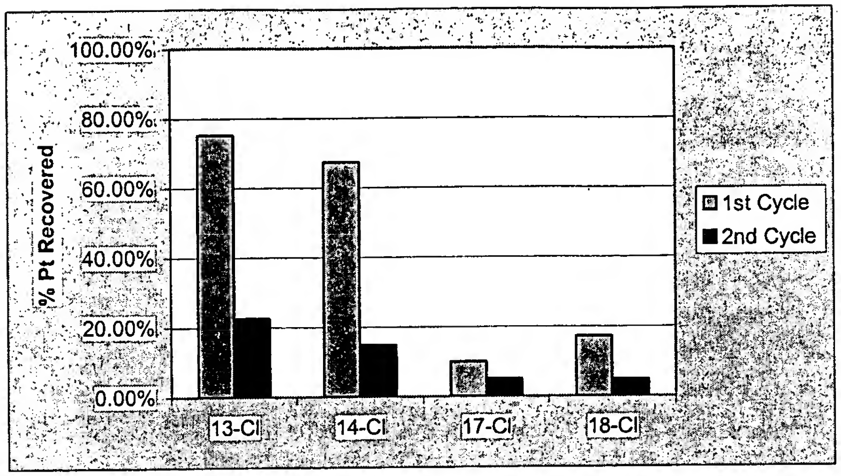


Figure 16. 13-Cl and 14-Cl outperform 17-Cl and 18-Cl and continue to extract a majority of PGMs at low concentrations.

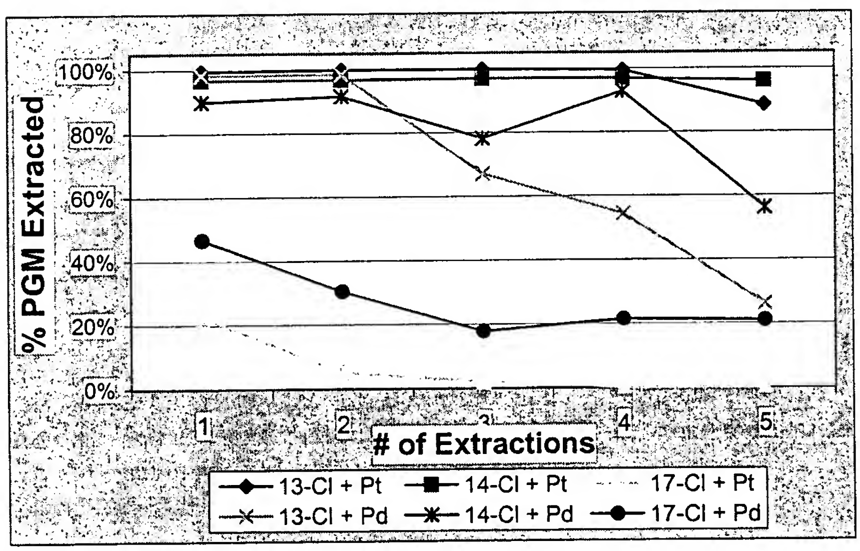


Figure 17. 13-Cl and 14-Cl continue to extract over 90% of PGM's in multiple extractions

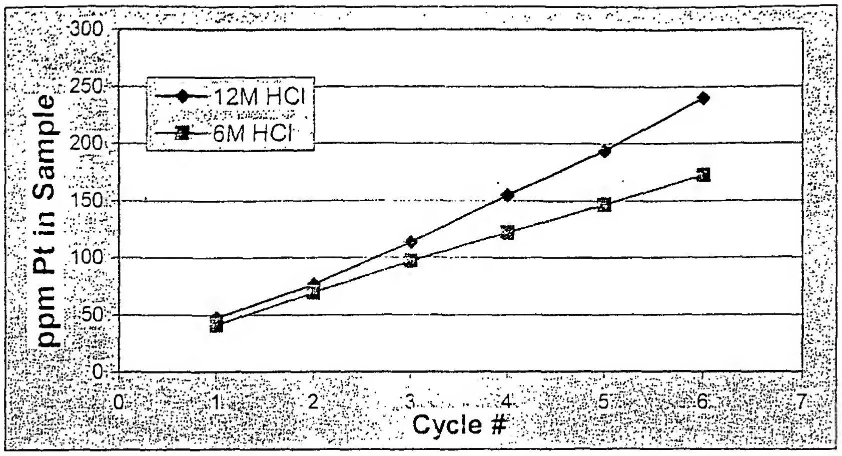
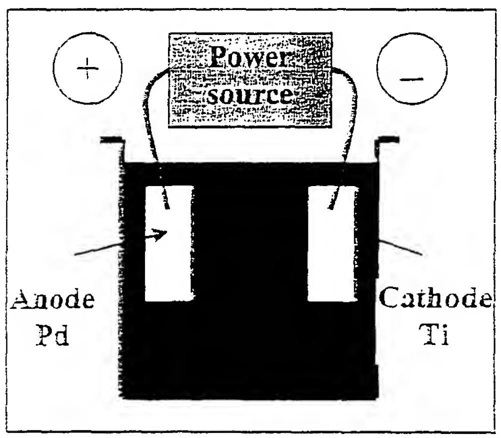


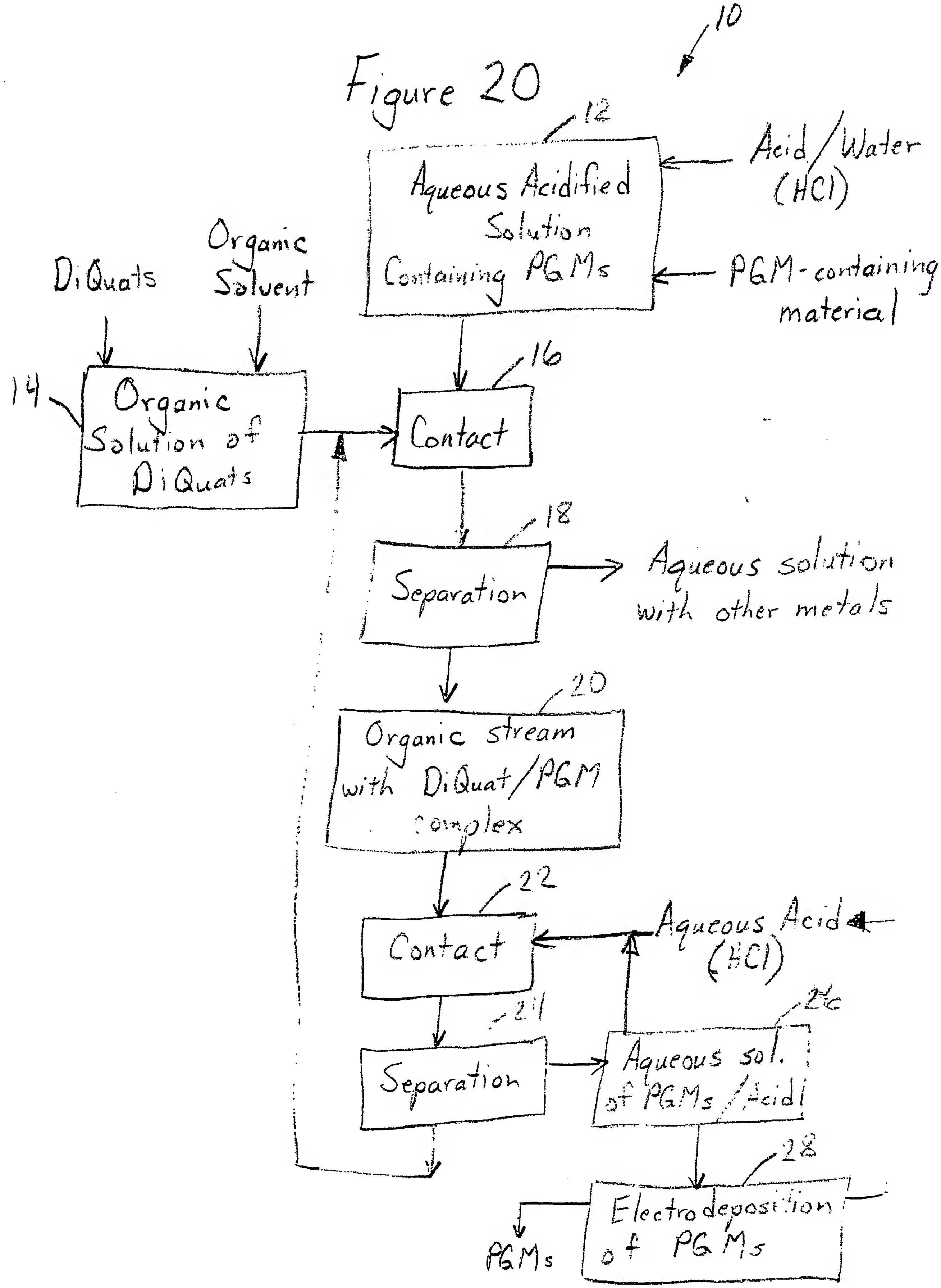
Figure 18. HCl can be reused effectively for multiple back extractions



Schematic diagram of electro deposition

Figure 19

Figure 20


10
12
Aqueous Acidified Solution Containing PGMs
Acid/Water (HCl)
PGM-containing material
DiQuats
Organic Solvent
14
Organic Solution of DiQuats
16
Contact
18
Separation
Aqueous solution with other metals
20
Organic stream with DiQuat/PGM complex
22
Contact
Aqueous Acid (HCl)
24
Separation
26
Aqueous sol. of PGMs/Acid
28
Electrodeposition of PGMs
PGMs